Weatherwise

Applied Meteorology Issue

October 1957

Volume 10 Number 5

"SOME PEOPLE ARE WEATHERWISE BUT MOST ARE OTHERWISE"—BENJAMIN FRANKLIN

WEATHERWISE

THE MAGAZINE ABOUT WEATHER

DAVID M. LUDLUM, *Editor* HENRY W. BULKLEY, *Associate Editor*

Applied Meteorology

THE employment of weather information in meeting the operational problems of business and industry provided the theme for the First National Conference and Workshop on Applied Meteorology at Hartford, Connecticut, on 28–29 October 1957. The sessions were attended by many of the nation's top professional meteorologists and by many leaders of business and industry from all parts of the country.

To provide the readers of *Weatherwise* with a better acquaintance of this vital subject, the entire current issue has been devoted to the activities of the conference. Four of the outstanding papers are reproduced in the following pages. The entire program has been listed on pages 147–8 to show the full scope of the meetings. In addition, the Professional Directory of companies engaged in the private practice of meteorology has been inserted on pages 168–9.

The Hartford conference and workshop was sponsored by the American Meteorological Society and was under the immediate supervision of the Connecticut Valley Branch of the AMS and the Hartford Chamber of Commerce.

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Front Cover: The control room at du Pont's Chambers Works, Deepwater, New Jersey, coordinates activities during severe weather situations. Represented are transportation, communications, power, protection coordination, personnel, maintenance, and flood warning service. A du Pont Company photo.

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Program of the First National Conference and Workshop of Applied Meteorology

Hartford, Connecticut—28–29 October

Monday Morning, 28 October

Address of Welcome, Richard B. Haskell, President, Hartford Chamber of Commerce.

Opening Remarks, Dr. Robert D. Fletcher, President, American Meteorological Society.

Weather Problems of Business and Industry I

Chairman: Walter P. Knauss, Executive Vice President, Manufacturers Association of Hartford County.

A Case of Applied Meteorology. Thomas S. Moorman, Maj. Gen., USAF, Air Weather Service, and Dr. Robert D. Fletcher, Director of Scientific Services, Air Weather Service, Washington, D. C.

DuPont's Tide and Storm Warning Service. Charles A. Evans, Organic Chemicals Dept., and George F. Collins, Engineering Dept., Wilmington, Del.

Moisture Damage to Ships' Cargoes. Norman L. Canfield, Chief, Climatic Analysis Section, National Weather Records Center, U. S. Weather Bureau, Asheville, N. C.

The Aircraft Industry and Meteorology. Robert D. Roche, Manager, Systems Evaluation Dept., Lockheed Aircraft Corporation, Marietta, Ga.

The Specifications of Climatological Probabilities for the Georgia Nuclear Aircraft Laboratories. Francis E. Courtney, Jr., Operations Research Specialist, Lockheed Aircraft Corporation, Marietta, Ga.

Discussants:

Capt. Howard T. Orville, USN (ret.), Consultant, Friez Instrument Division, Bendix Aviation Corporation, Baltimore, Maryland; *Mr. Fred A. Young,* Weather Advisor, Electric Boat Division, General Dynamics Corporation, Groton, Connecticut; *Dr. Richard W. James,* U. S. Navy Hydrographic Office, Washington, D. C.; *Dr. John C. Freeman, Jr.,* President, Gulf Consultants, Fairbanks, Texas.

Monday Afternoon, 28 October

Luncheon: Cities Room.

Speaker: Under Secretary of Commerce, Louis S. Rothschild.

Toastmaster: Clifton M. Bockstoce, Manager, Pittsburgh Plate Glass Company, Hartford.

Weather Problems of Business and Industry II—Hartford Room

Chairman: Frederic A. Berry, Admiral, (Ret.) USN, Advisory Committee on Weather Control, Washington, D. C.

Weather Problems of the Petroleum Industry. Forrest H. Blanding, Esso Standard Oil Company, New York, N. Y.

Using "Climatic Odds" to Estimate Fuel Oil Requirements. Loren W. Crow, Consulting Meteorologist, Denver, Colo.

Applied Meteorology in Public Utilities Company. Charles Pennypacker Smith, Supervising, Gas Supply, and Meteorological Engineer, Pacific Gas and Electric Company, San Francisco, Calif. and Francis J. Parsons, Jr., Senior Staff Meteorologist, Pacific Gas and Electric Company, San Francisco, Calif.

Meteorology as a Factor in Gas Load Dispatching. John R. Murray, Murray & Trettel, Consulting Meteorologists, Skokie, Ill.

Discussants:

Mr. William T. Jebb, President, Hartford Gas Company, Hartford, Conn.; *Dr. Woodrow C. Jacobs,* Director of Climatology, Air Weather Service, Washington, D. C.; *Mr. A. C. Hartranft,* Chief Load Dispatcher, Philadelphia Electric Company, Philadelphia, Penn.; *Mr. William J. Hartnett,* President, Weather Corporation of America, St. Louis, Missouri.

Monday Evening, 28 October

Social Hour: Cities Room.

Banquet: Hartford Room.

Speaker: James B. Burns, President, National Business Aircraft Association.

Toastmaster: Robert L. Carnahan, President, Connecticut Valley Branch, AMS.

Tuesday Morning, 29 October

Applications of Meteorology in the Development of Nuclear Power and in Atmospheric Pollution—Hartford Room

Chairman: Prof. E. Wendell Hewson, Dept. of Civil Engineering, University of Michigan, Ann Arbor, Mich.

Meteorological Studies in Connection with the Development of Atomic Energy. Joshua Z. Holland, Executive Secretary of the Advisory Committee on Reactor Safeguards, Atomic Energy Commission, Washington, D. C., and Maynard E. Smith, Leader, Meteorology Group, Brookhaven National Laboratory, Atomic Energy Commission, Upton, Long Island, N. Y.

Meteorological Phases of Air Pollution Problems Associated with the Operation of the Hanford Works. Glenn R. Hilst, Manager, Atmospheric Physics, Physics and Instrument Research and Development Operation, General Electric Company, Richland, Wash.

Hanford Experience in Utilizing a Meteorological Staff in Connection with Atmospheric Pollution Problems. Dr. Paul F. Gast, Manager, Physics and Instrument Research and Development Operation, Hanford Laboratories, General Electric Company, Richland, Wash.

The Application of Wind Tunnel Model Techniques in the Solution of Industrial Air Pollution Problems. Prof. Gordon H. Strom, Dept. of Meteorology and Oceanography, College of Engineering, New York University, New York City, N. Y.

A Practical Method for Estimating Dispersal of Atmospheric Contaminants. Dr. Harrison E. Cramer, Round Hill Field Station, MIT.

Discussants:

Dr. Leslie A. Silverman, Harvard University, School of Public Health, Boston, Mass.; *Mr. Harry Moses,* Radiological Physics Division, Argonne National Laboratory, Lemont, Ill.; *Mr. Donald H. Pack,* Meteorologist, Office of Meteorological Research, U. S. Weather Bureau, Washington, D. C; *Mr. Reynold L. Hoover,* Manager of Health and Safety, Reactor Development Division, Combustion Engineering, Inc., Windsor, Conn.

Tuesday Afternoon, 29 October

Luncheon: Cities Room.

Speaker: Prof. Henry G. Houghton, Head, Dept. of Meteorology, MIT, Cambridge, Mass.

Present Position and Future Possibilities of Weather Control.

Toastmaster: Reese H. Harris, Jr., Senior Vice President, Connecticut Bank and Trust Company.

Summary of Present Position and Future Outlook for Applied Meteorology Hartford Room

Chairman: Vernon Crudge, Director, Munitalp Foundation, Inc. New York City, N. Y.

Present Position and Future Possibilities of Short-Range Forecasting. Prof. Sverre Petterssen, Dept. of Meteorology, The University of Chicago, Chicago, Ill.

The Outlook for Long-Range Weather Forecasting and Climatology. Prof. Jerome Spar, Dept. of Meteorology and Oceanography, New York University, New York City, N. Y.

Operations Research Looks at the Weather Forecast. Jack C. Thompson, Office of Meteorological Research, U. S. Weather Bureau, Washington, D. C.

Whither Applied Meteorology in the United States? Dr. Thomas F. Malone, Director of Research, The Travelers Insurance Companies, Hartford, Conn.

Discussants:

Mr Robert M. White, Atmospheric Analysis Laboratory, Geophysics Research Directorate, U.S.A.F., Boston, Mass.; *Mr. Ward E. Duffy,* Editor, The Hartford Times, Hartford, Conn.; *Dr. Douglas L. Brooks,* Director of Research, Naval Warfare Analysis Group, U. S. Navy Dept., Washington, D. C; *Mr. John H. MacMillan, Jr.,* Chairman of the Board, Cargill, Inc., Minneapolis, Minn.

The Proceedings of the First National Conference and Workshop on Applied Meteorology will be published and distributed to those who register at the conference. A limited number will be available for sale through the Connecticut Valley Branch of the AMS.

A mobile unit of the North American Weather Consultants of Goleta, California, raises balloons with meteorological and chemical equipment for low-level sampling in an air pollution study.

Operations Research Looks at the Weather Forecast

J. C. THOMPSON, *Office of Meteorological Research, U. S. Weather Bureau, Washington, D. C.*

OPERATIONS research is a procedure for making use of the "scientific method" in order to provide quantitative information for making operational decisions. While the logic of this approach undoubtedly has been apparent for many years, it was not until World War II that it developed as a systematic method applicable to operational problems in general. Examples of attacks on specific industrial, agricultural, and military problems have been reported by a number of authors (1, 2, 3), and the application of operations research in meteorology has been receiving increasing attention during the past few years.

The approach to an operational problem involving the weather forecast should logically begin with an analysis of the operation itself. As a rule, this will require obtaining information on the economic, psychological, or other factors which appear to be important to the decision, or decisions, which are to be made. This is not always an easy task; in many cases the most difficult part

of the problem may be that of finding out what criteria should be used in deciding upon a course of action.

In a discussion of the operational criteria which should be important in deciding whether or not to cancel a scheduled airplane flight, Gringorton (4) has proposed that the net cost resulting from a cancellation should include such items as company overhead, cost of rentals, maintenance of idle equipment, and salaries of the airplane crew. The loss resulting from having the airliner return to the point of departure, or divert to an alternate airport if the destination is closed, should include overhead, salaries of the crew, cost of fuel and other expendables, and loss of prestige and inconvenience from the passengers' point of view. The latter item is typical of certain intangible factors which are extremely hard to evaluate quantitatively. Such parameters as customer satisfaction, good will, and psychological resistance to the acceptance of advice are all difficult to assess and to combine with the usual economic factors; yet their proper integration into the decision process is at times crucial to the successful use of the weather prediction.

The importance of psychological elements in the decision-making process is nowhere more clearly exemplified than in the case of warnings of disaster-type weather. Here, the decision must be based not only on the gravity of the impending disaster, but also upon the manner in which individuals and groups react to certain kinds of warnings. Williams (5) has pointed out that these factors include such questions as: Will people panic as a result of a warning, thus incurring increased danger to themselves and others? If a warning is issued and disaster weather does not occur, will this affect their reaction to future warnings? On the other hand, if the warning does not stress the worst possible contingency, will people fail to take adequate precautions? Unfortunately, there has been little or no systematic research on these questions. This, as Williams points out, is all the more unfortunate since these are typical of problems which could profitably be attacked by modern survey research techniques.

It should also be emphasized, perhaps, that the methods of operations research are particularly appropriate only for operations which, in whole or in part, are repetitive in nature. It is, in fact, this characteristic of most operations which makes them especially tractable when attacked by this method of analysis. Subject to the proper development and presentation of the weather forecasting information, operations research then provides for the most efficient use of the weather prediction itself.

The Weather Forecast

Every meteorological forecast which is issued as a categorical statement of the future weather is subject to some uncertainty as to its outcome. This is, in fact, a common characteristic of the predictive type of information involved in any decision-making process. The primary purpose of operations research is then to provide quantitative information concerning the magnitude of that uncertainty, and to develop procedures for using this information effectively.

The most useful quantitative measure of uncertainty is communicated through the language of mathematical expectancy—probability. Considered in all its aspects, the concept of probability is not simple. However, for practical purposes it is sufficient to consider the probability of an operationally critical weather event as being equivalent to the percentage frequency of its occurrence. It is then possible to collect and classify weather data into forms suitable for computing such percentage frequencies.

Perhaps the most familiar of these is the climatological expectancy. Here, it is only necessary to compute, for a sufficiently long period of record, the percentage frequency of occurrence of critical weather, perhaps subdivided into seasons, months, or other increments of the annual cycle. If it is then assumed that, in the long run, the probabilities so obtained will apply in the future, these data may be used to decide whether or not an operation which is affected by such weather may be worth carrying on.

It must be admitted that, in the past, such decisions many times have been arrived at, not through such logic, but through bitter experience. Yet climate is a major factor in dictating what crops may be grown profitably, what industries are suitable, and even what will be our living habits. In Florida and southern California, for example, the cli-

matological probability of freezing weather is so small that the use of anti-freeze in automobile cooling systems is usually unnecessary. Farther north in New England, however, the occurrence of sub-freezing temperatures is so frequent each winter, that anti-freeze is normally purchased by every automobile driver during the fall months as a matter of course.

Now the climatological probability, as described here, is useful only in prescribing whether it is desirable to take no protective measures at all (as in the case of automobile cooling systems in Florida); or whether protection should be provided continuously for a certain period of the year (as is true of automobile radiators in New England). However, in some situations it may be most efficient to take protective measures only when critical weather is anticipated, but not at other times. In some South Atlantic states, for example, sufficient protection for automobile radiators may be provided by insuring that the car is placed in a garage whenever cold weather threatens. It is in such situations that the weather forecast may be most useful and the meteorologist called upon to provide probability estimates of critical weather based upon his expert evaluation of the meteorological information at his disposal.

It is important to note that the forecaster's probability estimates are not different in form from the climatological expectancy; nor is there any difference in the basic principles involved in their use for making decisions. The characteristic which differentiates the climatological expectancy from the forecaster's probability is the additional information upon which the latter is based—information obtained from an analysis of the current meteorological situation. Some writers (3) have described this process of improving the prob-

Joseph Leedom, center, of Northeast Weather Service, Bedford Airport, Bedford, Massachusetts, telephones a highway construction client to expect two nights of hard freezes. Ralph Berry, left, and John Wallace, head of NWS, confer.

ability estimates by the addition of relevant information as that of increasing their "sharpness."

Probability estimates may be provided by the forecaster through a subjective analysis of the current meteorological situation. Such estimates are, however, affected by the forecaster's experience, his competence in evaluating the relative importance of various meteorological variables, and even his psychological approach to the weather forecasting problem. This means that considerable variation may at times be expected in the probability estimates attached to the same meteorological situation by different forecasters.

In order to eliminate, or at least alleviate, this difficulty, an engineering approach to weather forecasting has been making considerable progress during the past few years. These studies include graphical integration procedures (6), statistical stratification and/or correlation methods (7), and numerical solution of simplified physical equations (8). All of these techniques have in common the desirable characteristic of objectivity; which means that human differences in training, experience, and psychology do not affect the results. Not all of these objective forecasting methods provide explicit information concerning the magnitude of the uncertainty attending each prediction, but such probability data can always be obtained by the procedure of analyzing past forecasts.

Public Forecasting Decisions

The problem of issuing forecasts for public use is complicated by the wide range of economic and other risks for which provision must be made. This means that a categorical decision which may be appropriate for one group of recipients may, in fact, be completely useless for another group.

Attempts have been made from time to time to provide for this contingency by issuing predictions directly in terms of probability so that the decision-making process can be tailored by the recipient for his own operation. Such predictions have been inaugurated most recently by the Travelers Weather Research Center at Hartford, Connecticut, and by the U. S. Weather Bureau in San Francisco, California. The logic of this procedure cannot be denied, and evidence from these latter experiments indicates that an appreciable number of serious forecast users are able to benefit from this type of prediction.

Even in these experiments, however, it has been recognized that a significant segment of the public, following an economically unsound but mentally less fatiguing policy of letting the forecaster make their decisions for them, will ignore the advantages of the probability forecast and will continue to require a categorical statement of the expected weather. In order to fulfill this requirement, the forecaster finds it necessary to compromise on a decision which he feels will, on the whole, be of the greatest public benefit. Unfortunately, however, both the definition of "greatest public benefit" and the manner in which it should be achieved are not clearly understood. Because of the unquestioned difficulties involved in this problem, the forecaster not infrequently, and quite understandably, makes a decision which will result in the least public criticism should his prediction fail.

It seems clear that in this field, as in the case of the disaster-type warnings referred to earlier, additional research is needed. Such studies should include, not only the psychologist, the economist, and the meteorologist working alone, but all three making a joint attack upon this problem.

Conclusion

As is true of almost all scientific endeavor, our efforts to advance the science of meteorology are primarily directed toward obtaining a better understanding of nature's processes. This emphasis is, of course, quite proper, not only for its own sake, but also because the observations and analyses of the atmosphere which are prerequisite to understanding its properties also provide practical information required in many fields.

Nevertheless, as we continue to advance the meteorological science, it becomes evident that our increased ability to observe and analyze the atmosphere is not always accompanied by a corresponding improvement in the skill with which we are able to predict its future course. As has been pointed out by Sutcliffe (9) ". . . it must be admitted that a large proportion of our knowledge of the atmosphere, even of the new knowledge which forms an impressive total, has little prognostic value . . . weather forecasting makes but

slow progress in spite of the striking advances in meteorological science." It seems evident that, for the foreseeable future at least, weather predictions will continue to be dominated by deficiencies and indeterminancies which will make their outcome to a greater or lesser degree uncertain.

But while we may thus find it difficult to improve our forecasts through advances in the science, we may be able to increase the usefulness of the predictions when they are applied to the making of operational decisions. It is here that the field of operations research can make a valuable contribution.

This article was abridged from the full article published in the proceedings of the conference.

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A weather map is analyzed in terms of a specific client's problems by a meteorologist of the Weather Corporation of America, St. Louis and New York City. Photo by Harold Ferman.

Operations research meteorologist, Francis E. Courtney, discusses a weather problem and its effect on the aircraft of the future with Robert D. Roche, Systems Evaluation Department Manager. Photo by Lockheed Aircraft Corp.

The Aircraft Industry and Meteorology

ROBERT D. ROCHE, *Lockheed Aircraft Corporation—Georgia Division, Military Operations Research Engineering Division, Dept. Manager.*

ONE should not be surprised that meteorology finds a niche in a business that builds airplanes. What is surprising is the width and breadth of the problems the meteorologist uncovers. The logical starting point is long-range planning, or Operations Research.

OPERATIONS RESEARCH

Lockheed wants to build the aircraft which are best for its customers—military and commercial. Those aircraft are the ones that do the best job on a mission. To design these, an intimate knowledge of the mission, operational planning, the state of the art, and the cost must be available. By a scientific method of systems analysis, the many components of the problem are integrated into a composite answer—one that quantitatively describes the optimum system for the specific job, or a new way of doing the job. This is Operations Research, and in Lockheed, this function is performed in the Military Operations Research Engineering Division. A group of specialists representing the major scientific fields pool their talents to accomplish this long-range planning.

A meteorologist plays an important part on the team. Weather is involved in every mission and air operation. As we push higher and higher into the stratosphere, and approach space-flight, and as speed requirements increase, the problems become increasingly complex. The meteorologist on the Operations Research team must anticipate the weather problem, define it in terms of the total analysis, and express his answer in the common denominator required by the complete systems evaluation. It is a unique brand of applied meteorology that demands initiative and ingenuity.

Lockheed feels its greatest need for competent meteorological advice is in the Operations Research function. It is here that the meteorologist makes his most important contribution to the industry.

In this long-range planning function, the meteorologist is the sole authority speaking for his science. On the mixed team, he sits with status equal to that of the aeronautical engineer, the aerodynamicist, the economist, the mathematician, the physicist, the electronics specialist. He must make his contribution in the common language of the team, and from the perspective of the total problem. He will seldom be asked questions. He must often pose them, and invariably answer his own questions. All of the work is

classified, and deals with the future. We are today, for example, in the 1965–75 planning era. Usually, working so far ahead in the future, the meteorologist finds books and even experience fall short of the desired solution. The problems are new and difficult. One has only to consider how close we are to space flight to appraise the magnitude of the atmospheric problems facing us.

This, then, from management's point of view, is the outstanding contribution of a meteorologist in Lockheed: to anticipate the meteorological factors involved in aircraft missions of the future, and to solve these problems—so that the design concept will result in a "best" airplane.

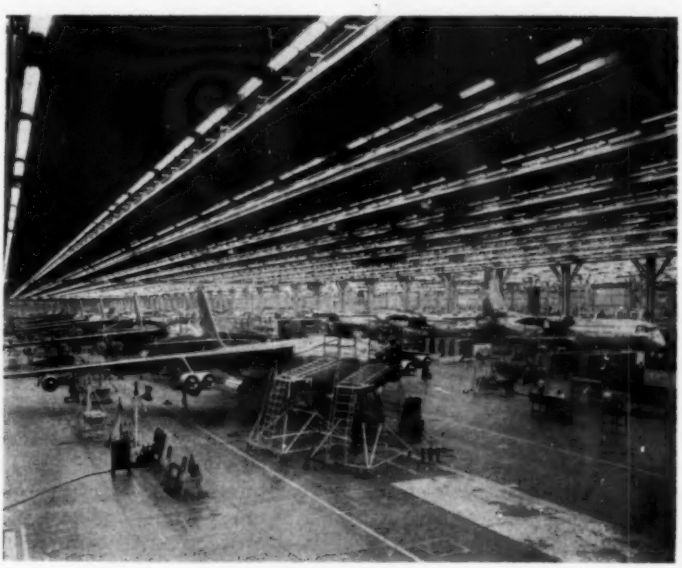
Engineering and Development

The next step, engineering and development, is another of importance for the meteorologist. Here his contributions are not so ephemeral, nor so futuristic. He may measure his worth more readily. There are numerous fine points of aeronautical engineering where an appreciation of the meteorological factors may eliminate or alleviate a design problem. It may involve as complex a problem as statistical analysis of gust characteristics and occurrence for a particular mission—or as simple a problem as standard atmosphere calculations or variations. In this area, once a meteorologist has his shingle out, his phone will start ringing. The customers are aeronautical engineers who know their business, and a surprisingly large amount of yours. But they are good customers. There is untold opportunity here for the professional meteorologist to uncover new areas that need attention and to initiate meteorological advisories that will simplify and assist the engineers in their design and development problems.

Late in the engineering stage, an experimental airplane or prototype takes shape, and flies. Flight test begins, and another phase of meteorological assistance becomes possible. This may, indeed, be the testing phase of prior meteorological contributions. The meteorologist may perform as a staff weather officer here, providing forecast and flight weather service to the Lockheed crews in first test flights. He may be called upon to establish meteorological limits of temperature or wind or pressure for static tests. Widely-varied, important, and interesting problems require the professional meteorologist to have a broad background and speak the language of engineers.

Airframe Manufacture

The next step in the life of an airplane—after research, engineering, and development



Lockheed's Georgia Division factory, the world's largest under one roof, has 77 acres of floor space. The assembly bay above shows the final lines for B-47 Stratojet modernization and C-130A Hercules production.

—is manufacture or production. Here, too, the meteorologist can assist. This area involves applications of industrial meteorology with which most weathermen are familiar. The control of manufacturing processes is often affected by meteorological conditions of temperature, humidity, pressure, and other elements. The experienced industrial meteorologist has but to walk through the manufacturing plant, along the assembly line, to see one operation after another that is amenable, in some degree, to improvement—in speed, cost, quality control—by meteorological analysis or advice.

Sales Engineering

By this time, the assembly line is turning out the new product. But the meteorologist in the aircraft industry is not yet through. The airplane must be properly described for the customer—and its capability clearly illustrated. It is surprising how helpful meteorological data can be in describing to the customer the performance of the airplane for his particular operation. Most frequently this takes the form of effects of weather on operational utility—cold weather/hot weather suitability tests, or mission profile analyses. Occasionally, existing climatic data suffices; more often, unique analyses are required. The meteorologist can help sell aircraft.

Special Facilities

The preceding comments deal with the uses for meteorology in the routine engineering and manufacture of aircraft. There may be special facilities in which meteorology service is absolutely imperative. The Georgia Nuclear Aircraft Laboratory at Dawsonville is an example of this. The routine operation of weather network and warning at such a special facility is a full-size job in itself. In many cases, nuclear facilities such as ours require meteorological control for certain reactor experiments. The importance of dependable and accurate weather information can hardly be overestimated.

The Status of the Meteorologist

This brief review has outlined for you the many areas in which a meteorologist can provide valuable services to an airframe manufacturer. It is appropriate to look at the requirements and position of the meteorologist in the corporation.

First of all, what does the Company look for in a meteorologist? If the primary contribution will be made in areas of Operations Research and long-range planning, the requirements are for a varied and lengthy experience in several fields within the science of meteorology, to include a substantial portion of aircraft operational work. The more exposure the meteorologist has had to other closely related sciences—such as physics, electronics, aerodynamics, aeronautical engineering, mathematics—the better will he fit into the team work required of him. A large amount of initiative, imagination, and ingenuity is necessary, and the experience record is examined for indications. One healthy indicator, always looked for, is research publications by the meteorologist. It is desirable that he have public speaking capability, for as a staff officer, one of his biggest jobs will be selling his ideas and analyses.

Once management has found their meteorologist, how do they most effectively use him? I have mentioned the long-range planning unit called Operations Research. In Lockheed, this is the most effective spot to place a specialist or a scientist whose duties are broad and carry him far afield. This places him in a division which reports directly to a top management executive, in this case, the Chief Engineer. Normally, this provides him with considerable mobility and authority within the organization, and permits full exercise of initiative. The title concomitant with this organizational location is hardly important. We feel the scope of the problems encountered make the individual more than a categorical meteorologist, and we prefer to designate him an Operations Research Specialist.

The Present and Future

This description of the status of the meteorologist would hardly be complete without enumerating a few facts of life, which might be considered disadvantages by some in the meteorological profession.

First of all, the meteorologist in the airframe industry is a little fish in a big pool. His scientific field is but one of a dozen or more that are strongly represented. Indeed,

many of the others are so vital to the cause that meteorology may be in the shadows. The imbalance is probably greater than in many other industries which are represented here. This does not deprecate the science; it is a statement of fact that must be philosophically accepted by the meteorologist in the airframe industry.

Secondly, the meteorologist is confined to applied science only. There is little room for *pure* research in this industry. Something has to roll out the factory door or the payroll will not be met. In the budget-conscious economy of today, man-hours must show a fairly direct relation to a present or future product to be acceptable. I have emphasized the word "pure" and imply a rigorous definition of pure research; the acceptance of *applied* research is whole-hearted—in fact, it is demanded, in meteorology as well as in the other sciences.

And a third item: the importance of the work and the difficulty of the problems combine to put the scientists in this industry under heavy and constant pressure. This includes the meteorologist. The job is demanding, more than many others in the meteorological field, but is comparably rewarding.

What of the future of meteorology in the airframe industry? It is my opinion that the need will increase steadily, in proportion to the complexity and cost of weapon systems, and the requirements of the Armed Forces and also the commercial air carriers. As we move into the era where flight is supersonic and stratospheric—whether manned or unmanned—whether propulsion systems are air-breathing or not—meteorology with overtones of atmospheric physics will be called upon increasingly often to anticipate the interference of the atmosphere, to take advantage of meteorological factors in flight, and to contribute to the engineering and industrial production processes. As nuclear power for aircraft becomes a reality, a whole new area of meteorological problems arise—not only in the aircraft operation, but also in the laboratory ground facilities. There is no doubt that the need will be great. Whether it will be satisfied will depend upon the initiative and enterprise of our scientists.

(*Continued on page 176*)

The Lockheed flight line at Palmdale, California, shows two new jets. At the left, the T2V-1 SeaStar is a carrier-based trainer; at the right is the F-104B Starfighter, a new addition to the USAF jet-age arsenal.

The meteorological tower at the Hanford Works emits smoke to test the atmospheric diffusion pattern. Photos by M. F. Scoggins.

Some Meteorological Problems in Nuclear Energy Production

GLENN R. HILST, *Hanford Laboratories Operation, General Electric Company, Richland, Washington*

THE operation of large nuclear energy plants, such as the Hanford Works, almost inevitably entails the problem of atmospheric pollution due to routine and non-routine emissions of radioactive or toxic materials. The present article emphasizes the meteorological factors important to the successful solution of this problem and describes the meteorological program developed to cope with this problem at Hanford. It should be clearly recognized, however, that the nature of the materials emitted and the biological and botanical effects of these materials are equally important, and a successful solution is possible only when all of these factors have been correctly integrated.

The Sources of Air Pollution at Hanford

Three major types of facilities are operated by the General Electric Company in the production of fissionable materials at the U. S. Atomic Energy Commission's Hanford Works. In the first, the fuel elements are prepared for irradiation. In the second, the fuel elements are irradiated in large nuclear reactors where uranium is converted to plutonium and a host of other isotopes, particularly fission products, are produced. The irradiated materials are then sent to the chemical separations plants where the useful isotopes are separated and purified.

Each of these facilities presents sources of atmospheric pollution. In fuels preparation, acid etching of fuel elements prior to cladding and the recovery of tailings and imperfect fuel elements give rise to acid mists and fumes which may be vented to the atmosphere. This is a problem common to many chemical plants.

The mammoth reactors which are operated at Hanford are water-cooled and for this reason much of the routine atmospheric pollution associated with air-cooled reactors is obviated. Ventilation air from the reactor building does contain some radioactive material, which is emitted routinely through tall stacks. However, the major pollution problem in these facilities is the potential for uncontrolled releases. Fortunately, we have had no experience which could define this problem exactly, but the large inventory of highly radioactive materials contained in one of these reactors makes the appraisal of potential pollution due to a reactor incident an extremely important part of the air pollution problem at Hanford.

Since the irradiated fuel elements which are handled in the separations plants contain large amounts of radioactive materials, as well as some very potent poisons, the processing of these elements gives rise to myriad possibilities for atmospheric pollution. The mere fact that these plants can be operated at all without injury to anyone is the highest tribute to the men who designed and perfected them. However, the potential for serious atmospheric pollution is sufficiently high as to require constant vigilance and a continual knowledge of the atmosphere's capacity to disperse these wastes. The most serious problems with regard to routine emissions at Hanford are associated with these separations plants.

Against this background of the sources of atmospheric pollutants at Hanford, the contributions of our staff meteorologists can be divided into three separate but related services.

Meteorological Consultation Services

When a new plant or facility is in the design proposal stage, every effort is made to anticipate all of the functional problems which may arise in the operation of that plant. It is at this stage that the potential for atmospheric pollution from the new plant should be evaluated and design criteria established. Alterations of a facility after its construction is complete are always expensive both in cost and lost production time.

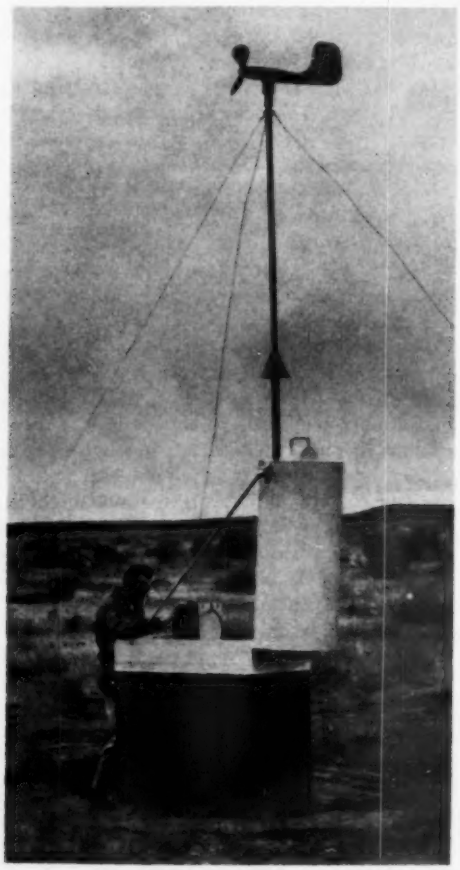
At Hanford a senior meteorologist is a regular member of a team of scientists and engineers who evaluate the potential hazards due to possible routine and non-routine emissions from each proposed facility and establish design criteria for that facility which will assure its safe operation. This meteorologist is called upon to estimate long- and short-term concentrations and dosages at various distances and directions from the plant site. These estimates are made for a variety of meteorological conditions and for various proposed plant sites, stack heights, building configurations, and types of emissions, e.g., continuous or sudden emissions and hot or cold effluents. By working as an integral part of the hazards appraisal team, the meteorologist is able to exert an optimum useful effort in picking and choosing among the wide variety of possible plant locations and designs so as to assure the safest possible plant.

The final design and location of the new plant quite naturally represent a compromise of all of the manifold requirements which must be met, and it is very likely that the optimum design from the meteorological viewpoint will not be met. But having worked directly with those who must finally decide how and where the plant will be built, the meteorologist knows why each decision has been made, has had every opportunity to inform these people of the consequences of the selected design (so far as the meteorological

factors are concerned), and can advise them clearly as to what design criteria must be incorporated on account of the meteorological factors. Generally, his assignment is completed when the proposed plant has been committed to construction.

A similar procedure is followed when design changes or alterations in the use of existing facilities are anticipated. These problems arise quite frequently in the operation of a plant as large and diversified as the Hanford Works. Again the consulting meteorologist works very closely with the design engineers.

It may be asked, "Why are these appraisals of the meteorological factors not made by the design engineers from accepted methods for estimating atmospheric diffusion and transport?" The answer is quite simple; methods for estimating the diffusive capacity of the lower atmosphere have not yet reached the stage of development where reliable answers can be obtained by simple models or handbook methods. This is an extremely complicated problem area and in the present state of knowledge reliable estimates can be obtained only by the judicious use of a variety of methods, and, what is even more important, assignment of reliable limits of uncertainty on these estimates requires a complete familiarity with the problems of turbulent diffusion.



A remote wind station is an outpost in the Hanford disaster warning service.

Advisories on the Diffusive Capacity of the Atmosphere

There are two basically different approaches to the problem of effluent control of industrial wastes. These are:

1. Recovery of all or a sufficiently large fraction of the waste materials at all times so as to assure safety under the most adverse meteorological conditions. This is the familiar "closed loop operation" concept.

2. Reduction of waste emissions, by either recovery processes or by direct control of plant processes, to safe levels in accordance with the current diffusive capacity of the atmosphere. This method is generally identified as "meteorological control."

The choice of containment or meteorological control is generally made during the design stage and, if waste recovery is at all feasible, the choice is almost always for containment. This choice is generally justified on the basis of plant operation without regard for variable meteorological conditions, thus permitting optimum use of the plant facilities. However, there are two circumstances under which meteorological control is either required or is economically justifiable: 1) when containment of noxious wastes is not physically possible and 2) when the cost of continuous full-scale recovery of wastes exceeds the cost of recovering only that part of the waste material which is required for safe operation according to the current diffusive capacity of the atmosphere. Such economic justification is, of course, only one of several factors which must be considered in making a choice of disposal systems; but, given assurance of safe operation, it is natural to look

for the most economical system of pollution control at the source.

The economic justification of meteorological control is, to the best of the author's knowledge, an unexplored question. It is relatively easy to set down the criterion of profitableness, namely, that the ratio

$$\frac{\text{Net Cost of Partial Recovery} + \text{Cost of Meteorological Advisories}}{\text{Net Cost of Total Recovery}}$$

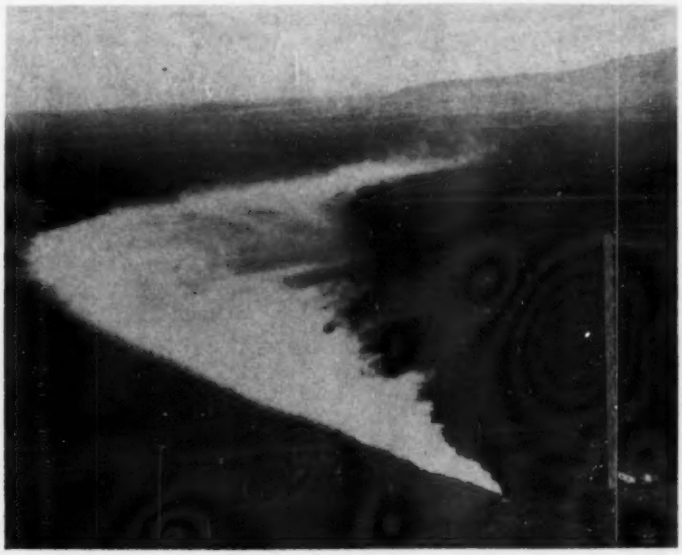
is less than one. The cost of waste recovery must include the cost of acquisition, operation, maintenance, and depreciation of the recovery equipment, the cost of storage or reprocessing of recovered wastes, and the market value, if any, of these wastes. If waste recovery is not profitable, partial recovery, or full utilization of the atmosphere for waste disposal, can produce very real dollar savings in plant operation since the atmosphere's diffusive capacity varies through at least two orders of magnitude. In terms of waste recovery operations, this means that the amount of material emitted per unit time may also be varied through at least two orders of magnitude. Clearly each situation must be appraised on its individual merits, but, when approached from this viewpoint, meteorological control takes its place as an integral part of plant operations.

Because of uncertainties in estimates of the diffusive capacity of the atmosphere, it is necessary to introduce safety factors in the meteorological advisories, the net result of which is to require greater recovery of wastes than is perhaps absolutely necessary. Insofar as the reduction of these safety factors lowers the net cost of either partial or total waste recovery, further researches into the processes of turbulent diffusion in the lower atmosphere are also economically justifiable.

In order to provide complete meteorological advisory services to the separations plants, a full-time weather service is operated at Hanford. The meteorological parameters necessary for specifying the diffusive capacity of the atmosphere are derived from wind and temperature measurements taken from a 400-foot meteorology tower located near the separations plants. A professional meteorologist is on duty at this station at all times. His duties, of course, include considerably more than the preparation of diffusion advisories since this station is responsible for all weather forecasts, observations, and climatological summaries needed for the operation of the entire Hanford Works.

Since our present knowledge of the relationships between the meteorological parameters and the diffusive capacity of the atmos-

(*Continued on page 174*)



A smoke plum spreads downwind under the scrutiny of Hanford meteorologists.

Professional Weathermen Serve TV

Francis Davis at Philadelphia's WFIL-TV is sponsored by the Bell Telephone Company.

A TV weather display prepared by Weather Engineers, Inc., of Sacramento, California, for the Pringle Tractor Company.

Professional meteorologist, James Fidler, provides "up-to-the-second," radar-scope pictures for his Cincinnati area audience over WLW-TV.

Oklahoma City's popular weatherman, Harry A. Volkman, is carried by KWTV.

The author telephones the Chambers Works of the du Pont Company with the latest weather advisory. In the background are an Aerovane recorder, a microbarograph, and a Delaware Bay tide recorder.

Du Pont Tide and Storm Warning Service

GEORGE F. COLLINS, *Engineering Department, E. I. du Pont de Nemours & Company, Inc., Wilmington, Delaware*

THE du Pont Severe Weather Advisory Service began operation in November 1953 with service to three Company locations. This service was started when it became apparent there was a need within the Company for special weather information which was not available or available in only a limited fashion from the local U. S. Weather Bureau.

Requests for weather information within the Company has steadily grown and the number of locations served in the last two years has varied from eight to twenty-one, depending primarily upon the number of active construction sites at any one time. Because of the nature of the services offered, weather advisories have been limited with few exceptions to locations along the Eastern seaboard from South Carolina to New Jersey.

PERSONNEL

The du Pont Company employs four engineers who are professional members of the American Meteorological Society. These men devote the major portion of their time to air pollution prevention activities or applied climatological problems. They also operate the weather office during severe weather.

FACILITIES

The Weather Advisory Service is a part of the Engineering Department and is located in the Louviers Building near Newark, Delaware, about 12 miles west of Wilmington. The weather office facilities include weather teletypewriters "A" and "C," a microbarograph, "Aerovane" wind recorder, and tide recorder for Breakwater Harbor, Delaware. More will be said about the tide recorder later. Temperature and humidity are recorded in a standard instrument shelter on the lawn of the Louviers Building.

Precipitation is not measured, but records are available from a Cooperative Observer at the University of Delaware three miles distant, or from the Weather Bureau office at New Castle County Airport just south of Wilmington. Recently a private water

company near the Louviers Building has started keeping precipitation records.

In addition to the above, several Company plants in the area keep weather records. Chambers Works, for example, keeps continuous records of wind, air temperature, sunshine, precipitation, river water temperatures and Delaware River tides at Deepwater, New Jersey.

Communications

In the weather office itself are two unlisted telephones whose numbers are known only to clients. One of these telephones can be answered at six different locations in the Louviers Building. All Company plants in the Wilmington area, including Chambers Works, as well as New York and Philadelphia, can be reached by telephone by direct dialing. The assistance of the telephone operator is needed on calls to more distant locations.

In the event a location cannot be reached by telephone, TWX service is available in a room adjacent to the weather office.

In emergencies a Bell System radio telephone is available.

When a severe weather advisory reaches the plant, key persons throughout the plant are notified by telephone or short wave radio. Some plants post the advisories on bulletin boards.

Functions of the Office

As stated earlier, the chief function of the Company weather office is to provide services which are not readily available from the local U. S. Weather Bureau office.

Our primary emphasis is on severe weather advisories and not routine day to day forecasts, although the latter are made on request. Each plant has established what for it constitutes "severe weather." At Chambers Works, for example, some of these limits are:

Temperature below 25° F.—Protect certain process lines against freezing.

Winds in excess of 25 mph—Suspend construction and maintenance activities on roofs and scaffolds.

Tide 3 ft. above normal—Sandbag areas subject to flooding.

Snow in excess of 2 in.—Clear plant roads and railroads.

The function of the Company meteorologists is to keep the plant informed as far in advance as possible of these critical situations. They should also follow through and notify the plant when these conditions are over. It is particularly important to notify the plant if there has been a change in the weather and the critical conditions will not occur.

Arrangements can be made in some locations to have the U. S. Weather Bureau notify the plant in cases of severe weather such as tornadoes, hurricanes, or floods. Priority of notification, however, is given to radio stations, newspapers, Civil Defense, local police and highway officials, American Red Cross and similar agencies. This is as it should be, but it means that industry is the last to be notified.

By having a Company weather office, there is always a meteorologist available to discuss critical situations. The Company office also can take the initiative and keep plants posted of impending bad weather, thus relieving management of that responsibility.

Another service the Company meteorologist offers is the ability to tailor the forecast to fit the particular plant location. A general forecast of abnormally high tides on the coast of Delaware or New Jersey, for example, does not necessarily mean that there will be abnormal tides at a plant up the Delaware River. The Company meteorologist has made a detailed study of his particular plant site and knows exactly what to expect with the different storm patterns. The Weather Bureau cannot be expected to make a specific forecast for every little bay and inlet in its area.

Routine Operations

It should be emphasized that the Company meteorologist is dependent upon the U. S. Weather Bureau, perhaps even more so than the average citizen. All the "raw material" for preparing weather advisories—the surface, upper air and ship observations—is collected and disseminated by the U. S. Weather Bureau teletypewriter circuits. A great wealth of information comes in over circuits "A" and "C" 24 hours a day. Various types of information for different geographical areas are transmitted at a scheduled time. Our weather office is usually

unattended, except in bad weather. For this reason time switches have been put on the teletypewriters to receive only the weather data we desire.

One meteorologist is assigned primary responsibility for following the weather for a week at a time. His daily routine runs something as follows:

8:15 A.M. Check for severe weather advisories or severe weather conditions on circuits "A" and "C."

Check U. S. Weather Bureau state and regional forecasts as received on circuit "C."

Plot and analyze 500 mb. upper-air chart.

Sketch surface analysis as made by Washington Office, U. S. Weather Bureau, on a blank map.

If no critical conditions are expected at any Company locations during the day, nothing further is done at this time.

12:00 Noon. Recheck circuits "A" and "C" for critical weather conditions.

Late weather reports are received from "C" circuit teletype by W. R. Chalker, left, and A. E. Boyer, meteorologists of du Pont's engineering department.

4:45 P.M. Final check for critical weather conditions and set time clocks for night operation.

If severe weather conditions appear to be developing, the meteorologist will plot and analyze several upper-air soundings and surface charts, sometimes on an hourly basis. Good use is made of the prognostic charts prepared by highspeed electronic computer at the Weather Bureau Analysis Center, Washington, D. C. The data for these charts are transmitted over circuit "C" in numerical code. If need be, the meteorologist will seek the assistance of one or more of his colleagues to keep clients continuosly posted. Night or weekend watches will be set up, if necessary, until critical conditions have passed.

Delaware River Tides

One of the most interesting phases of our operation and one of vital concern to Chambers Works is the prediction of abnormal tides on the Delaware River Estuary. For several years Chambers Works has maintained records of tides near the confluence of the Salem Canal and the Delaware River. It was long felt by plant personnel that, if they knew what the tide was doing at the mouth of the Delaware River, they would be in a better position to be prepared for abnormally high water at Chambers Works.

As subscribers to the Severe Weather Advisory Service, they turned to the Engineering Department for assistance in this matter. We learned that the Philadelphia Electric Company was also interested in the problem and had been negotiating with the Scientific Services Division of the United States Weather Bureau in Washington for assistance.

As a result of the severe hurricane season along the Atlantic Coast in 1955, the U. S. Weather Bureau received funds to institute the Storm Surge Project. In the Philadelphia area cooperation between the U. S. Coast and Geodetic Survey, the U. S. Weather Bureau, the Philadelphia Electric Company, and the du Pont Company resulted in the installation of a tide recording gauge at Ft. Miles, near the entrance of Delaware Bay. A leased transmission line operates recorders at du Pont's Louviers Building, the Philadel-

phia International Airport, and the Philadelphia Electric Company.

More recently, Philadelphia Electric has also installed, on its own initiative, telemetering gauges at Reedy Point, Delaware, and Race Streets, Philadelphia. In conjunction with the Chambers Works tide gauge and the U. S. Geological Survey river stage recorder at Trenton, New Jersey, it is now possible to obtain an instantaneous picture of the entire tidal pattern of the Delaware River from Breakwater Harbor to Trenton.

To study further the problem of water levels on the Delaware, an informal group of interested parties has met several times to exchange information. This group includes representatives from all of the U. S. Weather Bureau offices in the area, the U. S. Geological Survey, the U. S. Corps of Engineers, Philadelphia District, the U. S. Coast and Geodetic Survey, the University of Delaware Marine Laboratory, the Delaware State Highway Department, the United States Steel Corporation's Fairless Works, The Delaware Power and Light Company, The Philadelphia Electric Company, and du Pont. Others interested in the river have been invited to participate.

Research and Special Study

The telemetering tide gauge system has now been in operation for one year. During that year we have learned that predicting water level in a tidal river is far from simple. River stage due to upstream runoff, wind direction and speed, and astronomical tide all have to be combined to give the right answer.

Du Pont has devoted its efforts to correlating winds at sea with tides at Breakwater Harbor, and also correlating tides at Breakwater Harbor under different storm conditions with subsequent tides upstream at Chambers Works.

Philadelphia Electric has superimposed on one chart tide traces from Breakwater Harbor, Reedy Point, and Philadelphia. From these curves they are studying wave forms and arrival times at their locations in the Philadelphia area.

The U. S. Weather Bureau, Philadelphia, is the government agency officially responsible for predicting tides in the Delaware River Estuary. The Weather Bureau has attempted to separate the effect of upstream runoff from tidal effects in the area from Philadelphia to Trenton. The Bureau has also done some correlation of winds and tides in lower Delaware Bay. Much is still to be learned. It is hoped that the cooperative efforts of all interested parties as outlined above will bear fruit.

Economic Justification for Service

The Severe Storm and Tide Warning Service has proved of value to Chambers Works. The present cost of service to them is low compared to the cost protection which can sometimes be avoided. The cost is also low compared to loss which might be incurred with inadequate warning.

Even in a company the size of du Pont, there exists the problem of justifying a weather service to individual plants. A critical weather situation at a given location may occur only once a year or less. Under these circumstances, plant management is often reluctant to give financial support to the weather service. However, to provide for one severe situation, facilities have to be operated continuously throughout the year and the cost apportioned to the participating plants. This cost must be looked upon as an insurance premium. Periodic reevaluation of economic justification in light of experience and current Company operations is required.

An upper-air chart is discussed by du Pont meteorologists A. E. Boyer, foreground, and R. R. Palmer, of the engineering department.

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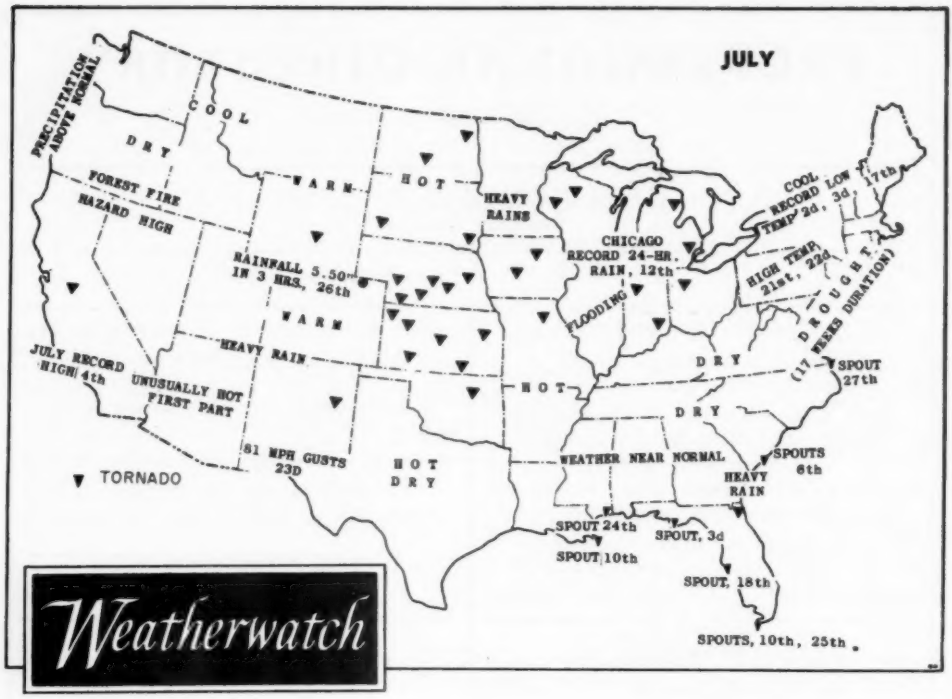


Northeastern Drought and Southwestern Hot Spell Feature an Otherwise Average Summer

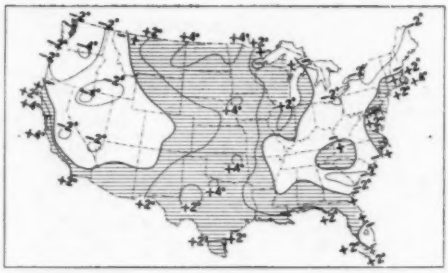
DAVID M. LUDLUM, *Editor*

The mid-summer months of 1957, July and August, showed remarkable resemblances in circulation patterns and resultant weather occurrences. After a rather abnormal month of June, when the country was divided into distinct thermal compartments and many weather extremes were registered, the elements became more placid, producing a sixty-day period of flow patterns which were quite typical of the season.

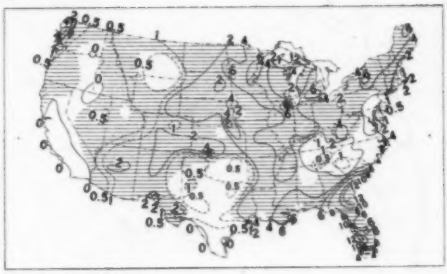
The temperature divisions in June had been in north-south zones: a warm West, a cool Great Plains, Missouri Valley, and upper Mississippi Valley, and a warm East. July and August, however, reversed this distribution. From the Great Lakes eastward to New England it was a rather cool and pleasantly sunny summer. Temperatures also averaged below normal in the Southeast. But in the central valleys it was generally warm—very warm from North Dakota southward to Texas and warmer than normal to the westward along the slopes of the Rockies and to the eastward as far as the Mississippi River. Though temperatures ran consistently above normal in the Plains, no monthly or seasonal records were set. In the Plateau and Northwest it was cool, but along the immediate California coast the mercury remained well above the July and August normals. At Los Angeles the temperature was above normal every day in July and it was the hottest August on record.

The outstanding abnormality of the season appeared in the persistent drought condition which plagued the Atlantic seaboard from May until near the end of August. From Massachusetts southwestward to the southern Appalachian highlands, rainfall deficiencies during the most important part of the growing season approached or exceeded all records. The results were far-reaching, with crops cut short, fields failing to produce a second yield of hay, and reservoirs sinking to dangerous levels by summer's end.

Elsewhere rainfall amounts approached or slightly exceeded the normals. The erstwhile drought area in the Great Plains received, for the most part, adequate moisture, and total crop yields were estimated as running close to the two banner years of 1948 and 1955. The only area of continued longtime drought lay in south-central Texas where the three summer months brought less than two inches of rainfall. But just to the west, in extreme southwestern Texas, the El Paso area reported excessive rains! Another area of excessive summer rainfall was Chicago, thanks to a 24-hour cloudburst on 12–13 July which dumped over six inches on that metropolis.



Departure of Average Temperature from normal in degrees Fahrenheit. USWB chart.



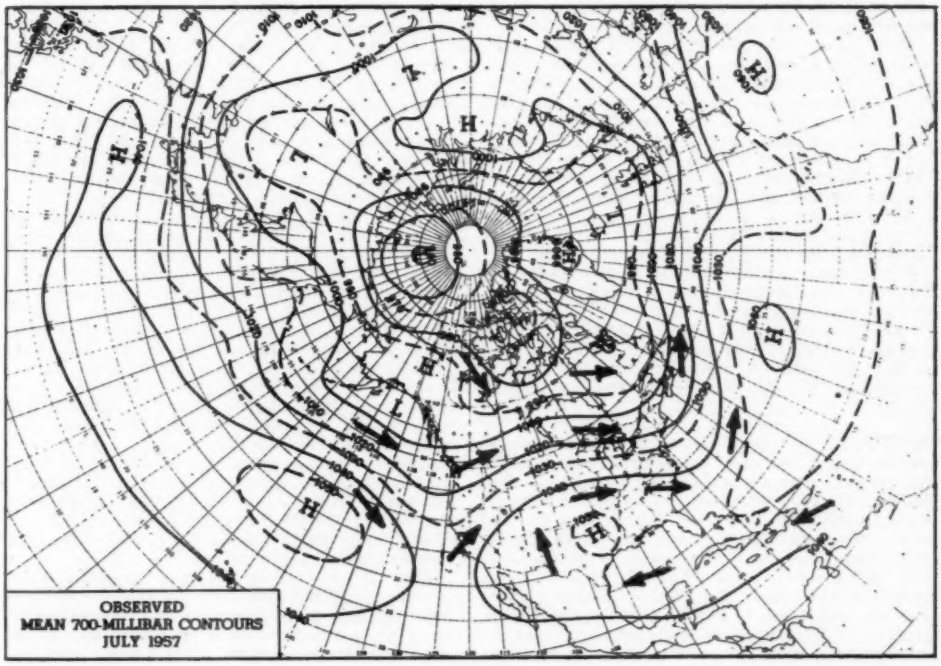
Total Precipitation in inches. USWB chart.

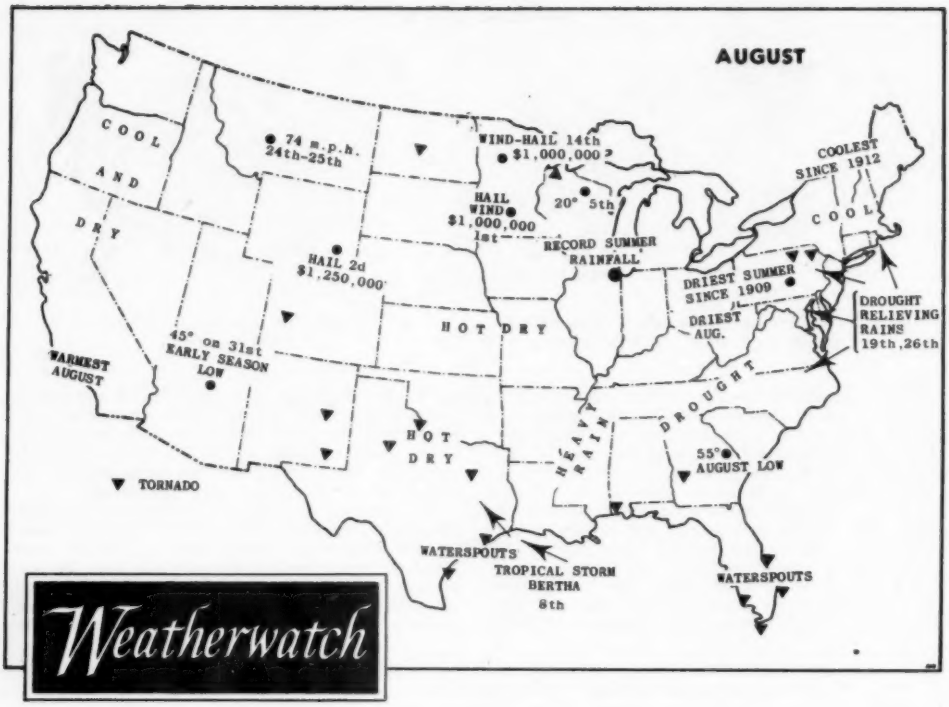
JULY—A western trough - central ridge - eastern trough pressure regime prevailed throughout the month without any substantial break. The summer-type circulation established itself immediately after the passage of Hurricane Audrey northward from the Gulf of Mexico to the Lower Lakes in the last days of June. With none of the permanent features of the July upper-air maps exhibiting any unusual departures from normal, the weather happenings of the month did not tend toward the spectacular.

Air flow from the Pacific Ocean into the far West was generally from west-southwest under the influence of the trough off the coast. Across the Plateau, the Rocky Mountains, and the northern and central Plains, upper winds streamed from the west in passing through the warm anticyclone over central areas of the country. East of the Mississippi River the prevailing flow came from the northwest as the trough off the East Coast was approached.

The center of the large anticyclone over the southern Plains throughout the month was usually found in the Oklahoma-Arkansas area, a position from which it could interdict the movement of any appreciable amount of Gulf air northward. Instead, the moist tropical air streams were forced to roam westward over southern Texas, New Mexico, and

The upper-air map below shows the pattern of air flow for January at about 10,000 feet, on which the average weather largely depends. The contours lines represent the mean height of the 700 mb. pressure level. Figures are in tens of feet: 1020 = 10,200 ft., 980 = 9,800 ft., etc. USWB chart.





Arizona where the elevated terrain triggered heavy showers on several days.

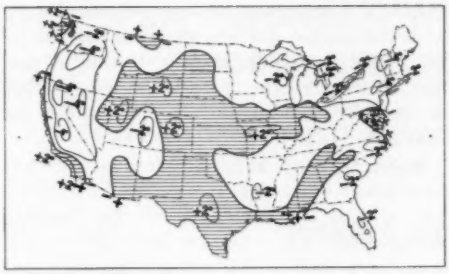
With no moisture from the Gulf of Mexico available, with the prevailing air flow consistently from the dry interior, with not a single coastal storm to tap Atlantic moisture sources—it was a dry time along the Atlantic coast. The greatest sufferers were southeastern Massachusetts and Rhode Island, southern New Jersey and southeastern Pennsylvania, and the Del-Mar-Va peninsula and Chesapeake Bay environs. Another very dry area under the same circulation conditions showed up in western South Carolina and eastern Tennessee. All of these regions received less than 25 per cent of normal rainfall during the summer. At Providence, R. I., Philadelphia, Pa., and Washington, D. C., to name a few, the drought for the growing season period, 8 April to 28 July, was the severest in the 85 years of Weather Bureau records. At Philadelphia only .65 inches fell in July, the lowest on record, and only .03 inches in August until the deluge of 3.36 inches on the 25–26th.

AUGUST—The upper-air circulation pattern in August closely resembled the general distribution of the pressure contours in July, as is often the case. Month-to-month persistence of weather types is more frequent for these two months than for any other two consecutive months; thus climatologists may characterize the two mid-summer months as a unit with greater accuracy than any other sixty-day period in the year. The chief development from July to August saw a general intensification of the pressure troughs and ridges, and a resultant speed-up in air flow to make the month somewhat more interesting from a meteorological point-of-view than its predecessor.

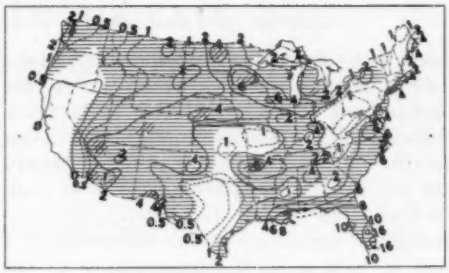
The large polar vortex north of Alaska in July deepened and at the same time the trough off the West Coast of the United States pushed further southward as far as Lower California. Between these two barometric depressions, pressure was much above normal over northwestern Canada, and a connecting ridge extended southeastward over the northern Plains to join with the semi-permanent anticyclone over the southern Plains.

To the east of the enormous ridge, which spread in an arc from Alaska to the Gulf of Mexico, lay a marked trough off the East Coast of the United States, stretching from a cyclonic center over northern Quebec southward over Maine and thence to the Bahama Islands off Florida. Pressure everywhere in the trough was well below normal, making it the dominant feature of the weather maps for eastern North America and the western Atlantic Ocean. A dry, northwesterly air stream flowed from the central ridge into the trough to continue and intensify the drought conditions which had held sway in the East since early May. Eventually, though, the trough served as the agency to break the long-continued dry period. It moved westward for several days to the ridge of the Appalachians and on the 25–26th permitted copious amounts of Atlantic moisture to fall on the coastal plain from New England to the Carolinas.

The charts of cyclonic and anticyclonic movement in August well illustrate the team work of the central ridge and eastern trough. The only weakening of its strength occurred on 8–10 August when tropical storm Bertha formed in the west Gulf and



Departure of Average Temperature from normal in degrees Fahrenheit. USWB chart.

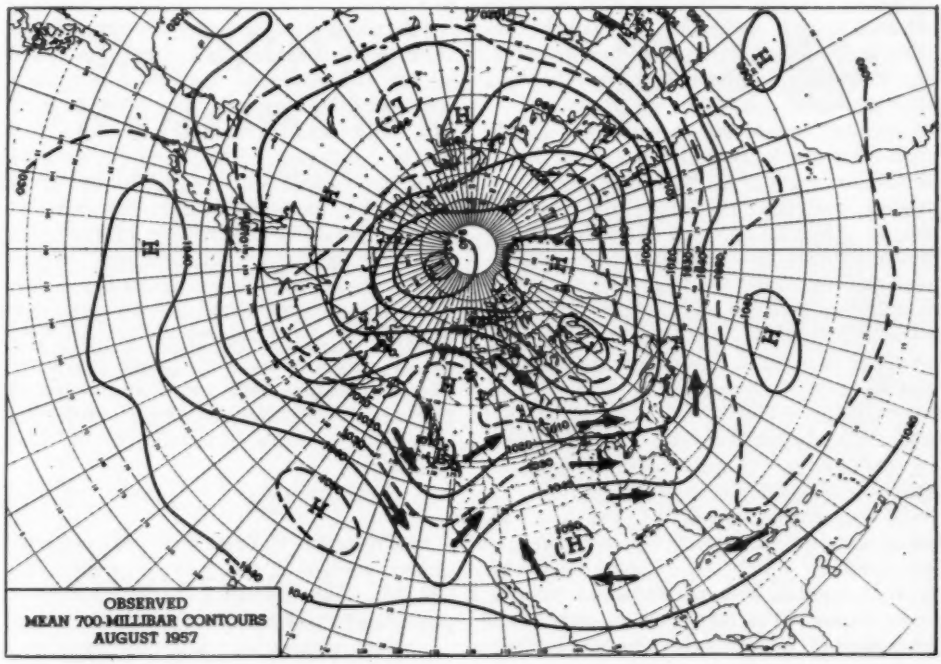


Total Precipitation in inches. USWB chart.

moved into northeastern Texas. There was some minor cyclogenesis in the northern Plains, but further west no cyclonic center was able to enter the coastline. In the East cyclonic activity was generally too far off the coast in the Atlantic trough to affect the mainland until mid-month. On the 18th a minor, but good rain-producing low moved through the Southeast and off Cape Hatteras. And on the 18th a larger disturbance affected the whole East Coast when the trough retrograded and generated a low over Georgia. This moved up the coastline as an excellent rain-producer, dropping as much as three inches on areas which had not seen that amount in a single storm since the preceding autumn.

The movement of anticyclones from northwestern Canada provided the most important pressure travel of the month. Seven highs took a course southeastward through the area between Minnesota and James Bay in Canada, each accompanied by a strong push of polar air, to bring pleasant temperatures and humidities to the Great Lakes and Northeast. Two highs developed central pressures above 30.50 inches (1033 mb). In each week of the month some locality from the Lakes eastward reported record-breaking date minima.

An interesting feature of the month took place in the eastern Pacific Ocean west of Mexico where three tropical disturbances were spotted during the month along the southern periphery of the Pacific high. Only one of these moved northward, that of 11–15 August, reaching within 400 miles of San Diego where it lost energy and dissipated.



Nuclear Energy Production

(*Continued from page 161*)

phere is by no means perfect, we also maintain a sizeable research group within the Atmospheric Physics Operation at Hanford. This group is engaged in a program of research which is specifically directed toward the problem of atmospheric diffusion at Hanford and the results of this work have important consequences in our consulting services as well as in the improvement of our diffusion advisories.

The Disaster Warning Services

Although every conceivable precaution is taken against untoward large-scale releases of noxious materials, there is always the possibility that such an event may occur. So long as such a possibility does exist, it is imperative that the potential consequences be properly appraised and methods for alleviating the damages be established. The problems of potential radiological hazards have been discussed widely in connection with the construction of nuclear power stations and other peace time applications of nuclear technology. Because the atmosphere provides a convenient vehicle for the transport of debris released in such an accident and largely controls the extent of damage due to this debris, the meteorological phase of this problem is a very important one.

Our staff meteorologists work very closely with other specialists in the appraisal of potential hazards due to large-scale releases of noxious materials. These appraisals include, among other things, the definition of the probable airborne concentrations in the vicinity of the source, estimates of fall-out of particulates and isodosage patterns from airborne contaminants, and probable trajectories of airborne materials for distances up to 200 miles from the source. These data are necessary to the evaluation of potential damages and for the establishment of logical courses of action which can minimize these damages, particularly bodily harm to people.

Of even greater importance than these hazards appraisal activities, however, are the preparations which have been made for prompt assistance in the event of a large-scale release. The first question which must be answered promptly is, "In which direction and how fast is the airborne material moving?" Safe evacuation of personnel must be accomplished quickly and in a safe direction. Simple extrapolation of the initial motion of the airborne material is not possible in irregular terrain such as surrounds the Hanford Works.

In order to answer this question, we have established a network of wind stations within and around the perimeter of the Hanford Works area. Up until now these remote stations have been of the autographic type and the data from these stations have been analyzed for regular patterns, which could be correlated with wind information and other data available continuously at the Meteorology Tower. This system has not been very satisfactory, and we are currently installing a radio-telemetering system which will make the current wind data from all of the remote stations immediately available to the forecaster on duty. These stations will also include equipment for the measurement of radioactivity. With this observational system, advisories as to the motion of airborne contaminants and the presence of radioactive contaminants at any one of the station sites can be relayed to a control center without delay.

The problem of long-range trajectories of airborne contaminants has been approached by way of a systematic analysis of hypothetical trajectories computed from synoptic wind data collected from weather stations in the Pacific Northwest. These trajectories have been summarized with regard to the probability that any point within 200 miles of Hanford would be affected by airborne contaminants originating at this site. These summaries provide clear delineation of preferred directions of travel and are extremely valuable in the concentration of any prerelease preparations which must be made. These calculated trajectories also serve as the basis for establishing reliable guides for forecasting probable trajectories at the time of a release.

Conclusion

The foregoing discussion of meteorological factors involved in the problem of air pollution due to the operation of the nuclear energy plants at Hanford highlights the many-

(*Continued on page 176*)

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The objects of the American Meteorological Society are "the development and dissemination of knowledge of meteorology in all its phases and applications, and the advancement of its professional ideals." The Society, a nonprofit organization, was organized at St. Louis, Mo., December 29, 1919, and incorporated at Washington, D. C., January 21, 1920. The Society is affiliated with the American Association for the Advancement of Science and the National Research Council of the National Academy of Sciences. Activities of the Society include its publications, national meetings and conferences, standing and technical committees, local branches, and services available through the Office of the Executive Secretary. Through grant from the National Science Foundation, the Society is participating in the National Register of Scientific and Technical Personnel.

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AMS Calendar, 1957–1958

Omaha, Neb.	Conference on the Upper Air	8–10 October
Hartford, Conn.	Workshop on Applied Meteorology	28–29 October
College Station, Tex.	General Meeting	13–15 November
Indianapolis, Ind.	With the Association for the Advancement of Science	26–31 December
New York, N. Y.	Annual Meeting	27–30 January
Kansas City, Mo.	General Meeting	25–27 March
Washington, D. C.	With the American Geophysical Union	5–8 May
Logan, Utah	With the Pacific Division of the AAAS	16–20 June
Ann Arbor, Mich.	Conference on Engineering Meteorology	9–11 September
Denver, Colo.	Conference on Practical Problems in Meteorology	24–26 September
Miami Beach, Fla.	Seventh Weather Radar Conference	18–21 November

Nuclear Energy

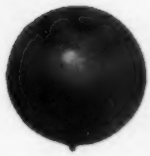
(*Continued from page 174*)

faceted nature of this problem. An active program of meteorological services and research has done much to assure the safe operation of the Hanford Works in this regard. In view of the all-important role of the atmosphere in dispersing airborne wastes, it would appear the contributions of the meteorologists are an indispensable part of the successful solution of the atmospheric pollution problem. However, the meteorologist's role in this regard is as a qualified and responsible member of a team of experts. Continued researches into the nature of atmospheric diffusion and transport will greatly enhance the value of this member's contribution to the successful solution of the problem of safe and economical use of the atmosphere for waste disposal.

Aircraft Industry

(*Continued from page 157*)

These few comments were designed to describe the activity of a meteorologist in the airframe industry, and his position with respect to management. Without design, the remarks have reflected the need of industry for competent scientific advice in all the related scientific fields. This is indeed true, and worthy of a lengthy paper. The marriage of science and industry is a reality, and that it is a productive union cannot be doubted. Meteorology in the Airframe Industry is a case in point.



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Statement on Detection, Tracking, and Warning of Tornadoes

The American Meteorological Society has recently released the following statement:

During the past few years there has been an ever increasing search for new or improved methods of forecasting severe local storms in the United States. Forecasting techniques have now been developed to the point that a positive forecast of tornadoes can be expected to verify in some portion of the forecast area about 50 percent of the time on a time range of six to twelve hours in advance. As a general rule, however, a forecast of severe local storms or tornadic conditions covers a much wider range in both time and space than is actually affected by the individual storm. For example, a tornado forecast can rarely be pinpointed, and usually covers an area of 30,000 square miles or more, while the area of destruction from a single tornado rarely exceeds ten square miles. Research has pointed to the existence of small-scale pressure patterns during the onset of severe local storms which, if identified in time, might help reduce the size of forecast areas. However, the collection and analysis of information needed for timely identification of these patterns pose many difficult problems yet to be solved.

Once the severe local storm forecast has been issued, the problem of issuing specific warnings for the general public becomes one of determining which particular thunderstorm cell within a given area will be the one that produces a tornado or a destructive windstorm. In this connection there are three primary tools at the disposal of the meteorologist: the first of these is the actual report of a visual sighting of the tornado or other severe weather conditions. Based upon one or a series of reports, the path of movement of the tornado may be determined and the task of alerting communities in its path may be conducted more intelligently. The second tool is weather radar. Radar has proved to be extremely useful not only in detecting thunderstorms but under some conditions, especially with radar surveillance from aircraft, it is possible to identify those more severe conditions which contain hail and would cause severe turbulence for aircraft. If an actual sighting of a tornado can be associated with a radar echo, the tornado can be tracked by radar continuously and thus facilitate the alerting of the communities in its path. From ground radar indications alone, however, it still remains difficult at times to determine with certainty the type and severity of surface weather which is associated with a particular rain echo. However, when this is possible, telephone calls are placed to the locality of the echo-producing storm, requesting a visual check of weather conditions. On some occasions the radar has indicated the peculiar "figure-six shaped" echoes in association with an active tornado. Unfortunately, this feature seems to be observed only at short ranges and under ideal conditions. Other storm features such as height and radar echo intensity are now under investigation, and preliminary results indicate that these characteristics should assist materially in identifying with ground radar potentially severe storms.

A recent development in the detecting of severe weather has been in the utilization of sferics detection equipment. It is known that each thunderstorm produces an electrical discharge. The sferics equipment now in use apparently measures the frequency of occurrence of this electrical discharge which has been found to furnish a rough correlation with the intensity of the storm. Such equipment measures only the direction of the storm from the detecting station and the approximate location of the storm may be determined by a triangulation technique utilizing three or more stations. To insure accuracy in the location of sferics-generating thunderstorms, radar is frequently used to supplement such data. Recent new developments in sferics equipment and techniques have indicated that the maximum of sferics activity may occur prior to the occurrence of tornado activity.

Current investigations indicate that the time between maximum sferics and tornado activity may depend on the type of receiving equipment. The observation of high sferics activity, therefore, should be of assistance in the preparation of short-range warnings of developing storms.

The results of current research with electronic equipment hold considerable promise of potential improvements in facilities for alerting the public to the probability of impending storms and a further saving of lives and property is to be expected.

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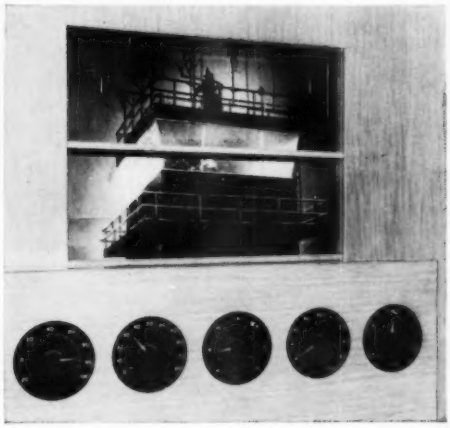

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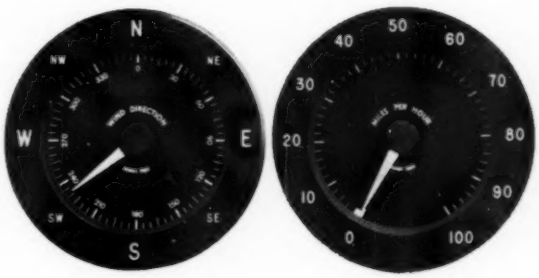

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